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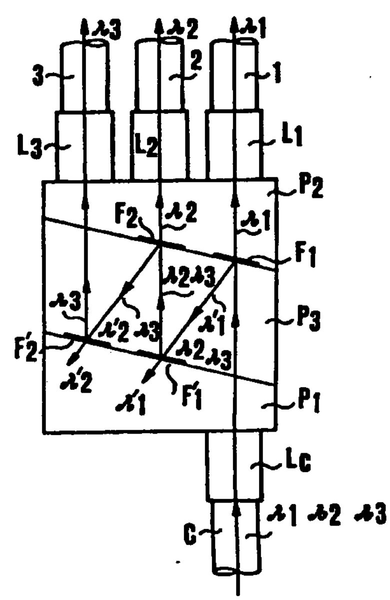
(54) Demultiplexer (multiplexer) for transmission systems in optical fiber.

(57) A demultiplexer for systems in optical fiber, that can also be used as a multiplexer without requiring any particular modifications, is described.

An input optical fiber, bearing n multiplexer signals, and n output optical fibers, are connected to the multiplexer.

(n-1) pairs of identical optical filters are installed along the course of the light rays inside the device: the signals that cross the filters of each pair that are met first by the light ray coming from the input optical fiber are output to the first (n-1) output optical fibers; the signal reflected by the other filter of the (n-1)-th pair is output to the n-th output optical fiber.



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DEMULTIPLEXER (MULTIPLEXER) FOR TRANSMISSION SYSTEMS IN OPTICAL FIBER

The present invention essentially concerns a demultiplexer for transmission systems in optical fiber, or in other words a device designed to separate, from one another, n signals (with a wavelength of λ_1, λ_2,..., λ_n) carried by an input optical fiber, sending them tidily upon n output optical fibers (the first signal, with a wavelength of λ_1, is sent on the first output optical fiber and so on).

The invention can be use, without requiring any special modifications, as a multiplexer: n signals (λ_1,..., λ_n) carried by as many input optical fibers are collected and directed towards an output optical fiber.

In optical fiber transmission systems, the realization of an efficient and relatively cheap demultiplexer is technically more complex than the realization of a multiplexer: for this reason, the invention will be described with particular reference to its use as a demultiplexer.

Over the last few years, transmission systems on optical fiber have begun to assume an ever greater importance in the field of telecommunications systems: the continuous, and considerable progress being made to improve the characteristics of optical fibers and of electro-optical (light source) and optical-electro (light detectors) transducers, is making frequency division (or, if preferred, wavelength division) multiplexing of an ever greater number of signals on the same physical support, more and more the up to date thing.

In such a situation, the problem of how to realize efficient filtering that makes it possible to separate the single signals, from one another, in the receiving part of the system, assumes an increasing importance.

In the traditional transmission systems (on cable or radio frequency carrier waves) the technician has a large number of types of filters available that are able to satisfy pratically every requirement: furthermore, an ever wider use is being made of programs that make it possible to optimize (with the

help of a computer) the design f the filters in function of the characteristics required, the response curve, dimensions, cost, etc.

For optical fiber transmission systems there are still no filters available with characteristics that may be compared to those of the traditional filters. In particular, the optical filters at present available present a noticeable reflection, even in the pass-band, and therefore are not able to discriminate between two signals with wavelengths that are almost the same. These poor characteristics of optical filters cause each demultiplexed signal to be "contaminated" by the other signals, during reception.

It is a well known fact that either diffraction reticles or dielectric multilayer filters deposited on glass can be used as optical filters; henceforth we will refer exclusively to the latter, which consist of a succession of several layers (from 20 to more than 30) of dielectrics with alternating high and low refractive indexes; by proportioning the thickness and number of layers in an opportune manner it is possible to give the filter the desired characteristics.

The invention consists in a demultiplexer (multiplexer) for transmission systems in optical fiber, which includes:

- a first and a second optical prism, identical to one another, to which are connected a common optical fiber, carrying $\underline{n}\ \lambda_i$ (λ_1, λ_2,..., λ_n) signals multiplexed to one another, and further $\underline{n}$ single optical fibers, each of which carries only one of the $\underline{n}\ \lambda_i$ signals;
- a third optical prism placed between the first and the second optical prism;
- a plurality of optical filters, placed respectively between the first and the second prism, and the third prism, that determine the course of the light rays inside the third prism.

The said plurality of optical filters is constituted by (n-1) pairs of filters that are identical, two at a time, to one another: to (from) the first (n-1) single optical fibers are sent (come) the light rays that travel across the filters of each of the said (n-1) pairs met first by the light rays as they come out of the common optical fiber, whilst to (from) the n-th output optical fiber are sent (come) the light rays reflected from the second filter of the (n-1)-th pair.

The invention will be described in greater detail with reference to an example of realization of a demultiplexer, described with the help of the attached figures wherein:

- figure 1 shows the diagram of a well known type of demultiplexer;
- figures 2 and 3 respectively show diagrams of a demultiplexer, and a multiplexer, realized according to the present invention.

Before examining the diagrams illustrated in figures 1, 2 and 3, let us recall that in optical fiber systems it is preferred that the signals be characterized by their wavelengths λ and that, given two signals λ_1 and λ_2, if λ_1 belongs to the pass-band of a filter F, the filter F will let λ_1 pass, and, in theory, only reflects λ_2; in actual fact the filter F also reflects λ_1, for example, attenuated by 15 dB.

We will refer now to the diagram in figure 1, wherein the common optical fiber (henceforth referred to as the input one) C carries three signals (λ_1, λ_2, λ_3) to the demultiplexer which includes an element in optical glass S with parallel faces, prisms in optical glass P_1, P_2, P_3 and P_4 and some optical filters F_1, F_2, F_3 and F_4. In the diagram, only the axis of symmetry of the beam of light rays, made parallel by the dielectric lenses L (L_C, L_1, L_2, L_3), have been shown.

At the present state of art, the optical filters whose real characteristics are nearest to the theorical ones, are band-reject filters: therefore we will presume that in the circuit shown in figure 1 the filters are all of the band-reject type.

The signals λ_1, λ_2, λ_3, carried by the fiber C, reach a first filter F_1 that allows λ_1 to pass, and reflects λ_2, λ_3 and λ_1 attenuated by 15 dB (in the figure λ'_1).

λ_1 is concentrated by the lens L_1 into the first single optical fiber (henceforth referred to as an output one); the signals λ'_1, λ_2 and λ_3 reach the second filter F_2 which lets λ'_1 and λ_2 pass and reflects λ''_1 (λ_1 attenuated, by 30 dB), λ'_2 (λ_2 attenuated by 15 dB) and λ_3.

On the output of the second filter F_2, the signal λ_2 is "contaminated" by a signal λ'_1 which, although attenuated by 15 dB, still has a width such as to

interfere in an unacceptable manner with the signal λ_2; therefore it is necessary to insert a third filter F_3, which eliminates λ'_1, between the filter F_2 and the lens L_2 of the second output optical fiber. In the same way, a fourth filter F_4, placed between F_2 and the lens L_3 of the third output optical fiber, eliminates λ'_2 and λ''_1 which in any case is so weak it can be ignored (it has been omitted in the diagram).

Therefore the demultiplexor of the known type described in figure 1 requires four filters that are all different from one another, which makes it very expensive.

In fact, the design of a multilayeer filter is a long and expensive job, it being necessary to also solve all the problems deriving from the limits that the present deposition techniques present, as far as the possibility of checking the deposition thicknesses and therefore the reproducibility of the filter thus obtained, are concerned; on the other hand, once the productive process has been defined, it is possible to obtain a large number of identical filters at a relatively low cost by depositing the dielectric layers on a support in optical glass of relatively large dimensions and then cutting it, in the same manner as is usually used for producing semiconductor circuits.

The demultiplexer designed according to the invention and illustrated in figure 2 differs essentialy from the known type shown in figure 1 because it requires only two different types of filters which makes its design and production much less expensive.

This economic advantage becomes ever more evident the higher the number n of signals to be demultiplexed is: in fact the known type of circuit illustrated in figure 1 requires the designing of 2 (n-1) types of filter that are different from one another.

A further advantage of the circuit made according to the invention is the fact that the multiplexed signals come out parallel to one another and orthagonally to the base of the prism P_2, without requiring the interpositioning of further prisms such as for example those indicated in figure 1 by P_1, P_2, P_3 and P_4.

The signals λ_1, λ_2, and λ_3 carried by the input optical fiber C are sent to a first filter F_1 which lets λ_1 pass (this is concentrated by the lens L_1 onto the first output optical fiber) and reflects λ'_1 (in other words λ_1 attenuated by 15 dB), λ_2 and λ_3 onto a second filter F'_1, that is identical to F_1.
The filter F'_1 lets λ'_1 pass (this can be freely left to go on into the prism P_1 or, preferably, dissipated onto absorption means that can be realized, for example, by blacking out the face of the support that is in contact with the prism P_1), and reflects onto a second filter F_2, the signals λ_2, λ_3, and λ''_1 which, having been attenuated by 30 dB, can be ignored (is has been omitted in the figure).
F_2 lets λ_2 pass (this is concentrated by the lens L_2 onto the second output fiber) and reflects λ'_2 and λ_3 onto a second filter F'_2 that is identical to F_2. F'_2 lets λ'_2 pass (the energy of this can be left to freely exit from the prism P_1 or else be absorbed, for example, by blacking out the face of the support that is in contact with the prism P_1) and reflects λ_3 (λ''_2 or λ_2 attenuated by 30 dB, can be ignored) which is concentrated by a third lens L_3 onto the third output optical fiber.
In figure 1 and 2 the optical filters have been symbolically represented by means of a thicker line along the separation surface between two prisms: this is only a semplification of the grafic representation of the demultiplexers. In actual fact the filters appear as components of a certain thickness inserted between two prisms: in order to avoid discontinuity in the physical course of the light rays in the transition areas, between two prisms, where there is no filter, it is necessary to insert small plates of optical glass, which will not interfere with the course of the rays themselves, between the prisms.
It is also best to use band-reject filters for the example of realization of the invention illustrated in figure 2 (F_1 and F'_1 have to reject λ_2 and λ_3, F_2 and F'_2 have to reject λ_3); without straying from the ambit of the invention (and by choosing the cutting frequencies accordingly) it is possible to use band pass filters.

Now by referring to figure 3, we will summarily describe the use of the invention for a multiplexer: the signals λ_1, λ_2 and λ_3 are input to the multiplexer through the corrisponding optical fibers and are multiplexed onto the optical fiber C.

λ_3 is reflected by F'_2 and F_2; λ_2 goes through F_2 and is output, together with λ_3, onto F'_1 which reflects them onto F_1; λ_1 goes through F_1 and is output onto optical fiber C together with λ_2 and λ_3, reflected by F_1.

Again without straying from the ambit of the invention, it will be possible for a person skilled in the art to carry out all the variations suggested by experience and/or technological progress to the device described herein and illustrated in figures 2 and 3.

CLAIMS

1) A demultiplexer (multiplexer) for transmission systems in optical fiber characterized by the fact that it includes:

- a first and a second optical prism, that are identical to one another, to which are connected a common optical fiber, carrying n signals λ_i (λ_1, λ_2,..., λ_n) and n single optical fibers, each of which carries only one of the n λ_i signals;
- a third optical prism placed between the first and the second optical prism;
- a plurality of optical filters placed respectively between the first and the second, and the third prism, which determine the course of the light rays inside the third prism;

characterized furthermore by the fact that the said plurality of optical filters is made up of (n-1) pairs of filters (F, F') which are identical to one another in pairs, as well as by the fact that to (from) the first (n-1) output optical fibers are sent (come) the light rays that travel through the filters (F_1, F_2, F_{n-1}) of each of the said (n-1) pairs met first by the light rays being output from the common optical fiber, whilst to (from) the n-th output optical fiber are sent (come) the light rays reflected by the second filter (F'_{n-1}) of the (n-1)-th pair.

2) A demultiplexer (multiplexer) as described in claim 1 characterized by the fact that to the first prism (P_1) there is only the common optical fiber (C) connected, and by the fact that the n single optical fibers, that are all connected to the second prism (P_2), are parallel to one another and to the common optical fiber (C).

3) A demultiplexer (multiplexer) as described in claims 1 and 2 characterized by the fact that it includes means designed to absorb the energy of the light rays that travel through the second filters (F'_1, F'_2,...,F'_{n-1}) of each of the (n-1) pairs.

4) A demultiplexer (multiplexer) as described in claim 3 characterized by the fact that the face of each of the said second filters that comes into contact with the third prism (P_3) is blacked out.

5) A demultiplexer (multiplexer) as illustrated in the aforegoing description with the help of the attached drawings, as also any isolated or combined parts of the same.

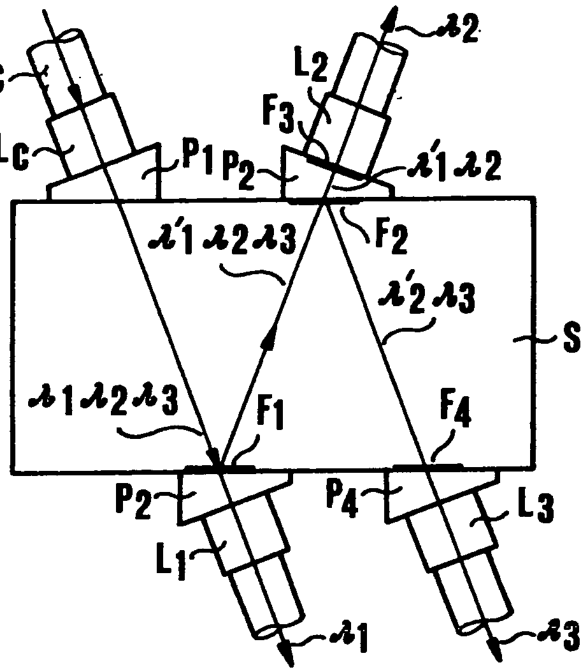

fig.1

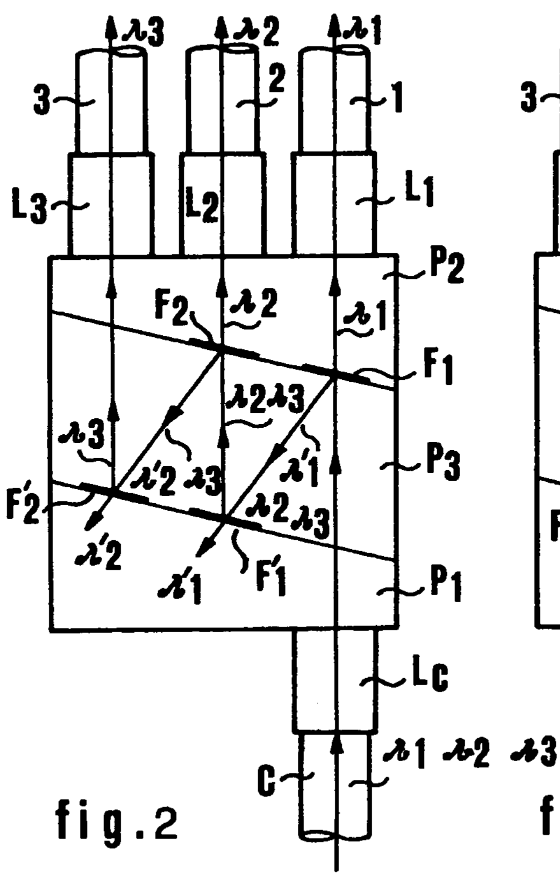

fig.2

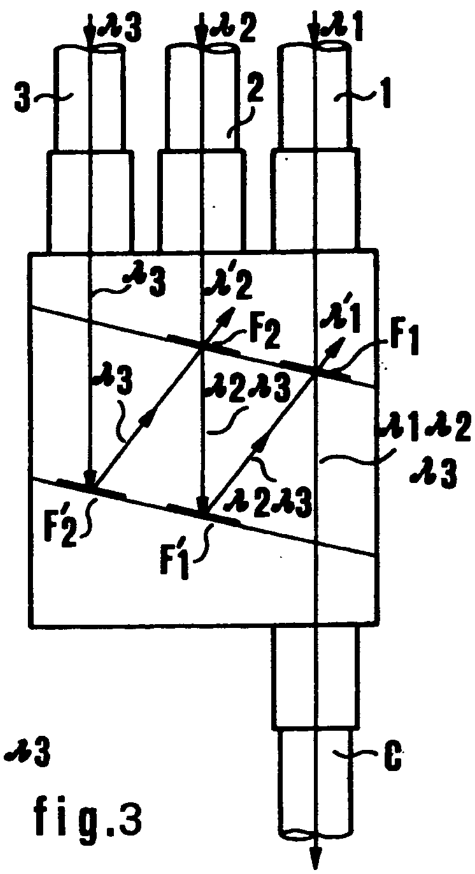

fig.3